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U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

CRASH INJURY INVESTIGATION

U. S. ARMY

HU-1A BELL IROQUOIS HELICOPTER ACCIDENT

Fort Carson, Colorado • 7 May 1962

Contract DA-44-177-TC-802

TCREC Technical Report 62-87

prepared by :

AVIATION CRASH INJURY RESEARCH
PHOENIX, ARIZONA
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FLIGHT SAFETY FOUNDATION, INC.
NEW YORK, NEW YORK

FSF

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This report was prepared by Aviation Crash Injury Research, a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-TC-802. Views expressed in the report have not been reviewed or approved by the Department of the Army; however, conclusions and recommendations contained therein are concurred in by this Command.

FOR THE COMMANDER:

FOR KENNETH B. ABEL
Captain TC
Adjutant

APPROVED BY:

WILLIAM J. NOLAN
USATRECOM Project Engineer

Task 9R95-20-001-01
Contract DA-44-177-TC-802
November 1962

U. S. ARMY HU-1A BELL IROQUOIS HELICOPTER
Fort Carson, Colorado
7 May 1962

Report of Crash Injury Investigation
AvCIR 62-14

Prepared by
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Phoenix, Arizona

for

U. S. ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

CRASH INJURY INVESTIGATION

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CONTENTS

ILLUSTRATIONS

SUMMARY

A U. S. Army HU-1A Bell Helicopter crashed on 7 May 1962 at 0906 hours. The crash occurred while the helicopter was conducting a service mission on the Fort Carson Military Reservation.

A total of six persons were aboard the helicopter at the time of the crash, including one crew member and five passengers. Five of the occupants received varying degrees of injury, ranging from minor to severe, and one was a fatality.

A crash injury investigation of the accident was conducted by Aviation Crash Injury Research (AvCIR) under the provisions of U. S. Army Transportation Research Command contract DA 44-177-TC-802.

The investigation revealed that the predominant cause of injury was the failure of all roof support members. A continuing trend in the failures of the carriage attachment fittings in the crew seats was also noted; although not contributing to the injuries experienced in this accident, such failures are extremely dangerous because they directly affect the restraint of the occupant.

As a result of the crash injury investigation, it is recommended, in part, that:

1. Consideration be given to the installation of a suitable roll-over structure in all HU-1A aircraft to prevent the roof structure from collapsing into the occupied area of the aircraft.

2. The aft-crew-seat carriage attachments be modified in the field to increase their strength (see TCREC Technical Report 62-84 for details of modification).

CONCLUSIONS

1. The vertical roof support members in the HU-1A will not support the overhead structure under roll-over conditions, or under moderate impact conditions.

2. The cast magnesium, aft-seat carriage attachment (Part No. 204-070-742), of the pilot and copilot seats failed under the moderate impact loads experienced in this accident.

3. The anchoring of the passengers' seat belts to the aft-seat support members, approximately 4.5 inches higher than the installed safety belt attachment fittings, permitted the restrained occupants to "submarine" under their seat belts, exposing them to unnecessary internal and/or spinal injury.

4. The pilot's helmet (APH-5) failed because of stress concentration caused by the sharp edges of the visor keeper.

RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. Consideration be given to the installation of a suitable roll-over structure in all HU-1A aircraft to prevent the roof structure from collapsing into the occupied area of the aircraft.

2. The aft-crew-seat carriage attachments be modified in the field to increase their strength (see TCREC Technical Report 62-84 for details of modification).[1]

3. The passenger compartment seat belts be attached to the firewall so that the belt crosses the iliac crest at 45 degrees. (See TCREC Technical Report 62-45 for permanent and temporary retrofit recommendations.)[2]

4. Helmet shells be free of external stress concentration points and that they be designed to provide progressive deformation of the liner before shell failure occurs in localized areas.[3]

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1. Avery, Dr. J. P., Strength Analysis of Carriage Attachment Fitting on Crew Seats, HU-1A Aircraft and Recommendations for Improvement. TCREC Technical Report 62-84, AvCIR 62-11, U. S. Army Transportation Research Command, Fort Eustis, Virginia, August 1962.

2. Robertson, S. H., Shook, W. H., Haley, J. H., Jr., Modifications to the Passenger Seat-Belt Tiedown Attachments in the U. S. Army HU-1A Series Bell Iroquois Helicopter, TCREC Technical Report 62-45, AvCIR 62-1, U. S. Army Transportation Research Command, Fort Eustis, Virginia, May 1962.

3. Schneider, D. J., Capt. MC, U. S. Army, Walhout, G. J., Helmet Design Criteria, Based on the U. S. Army APH-5 Helmet Evaluation, TCREC Technical Report 62-57, AvCIR 62-6, U. S. Army Transportation Research Command, Fort Eustis, Virginia, April 1962.

DESCRIPTION OF THE ACCIDENT

HISTORY OF THE FLIGHT

At 0906 hours, 7 May 1962, U. S. Army HU-1A Bell Helicopter, Serial No. 60-3543, crashed while on a service mission within the Fort Carson military reservation. Aboard the aircraft were the pilot and five passengers. One of the passengers occupied the copilot seat and throughout the remainder of this report will be referred to as the copilot.

Prior to the crash, the pilot was attempting to fly out of an apparent high rate of sink caused by some unknown factor, or probably a combination of unknown variable factors. In an effort to check the high rate of sink, the pilot applied collective pitch and noted a drop in rotor and engine r. p. m. ; collective pitch was lowered and applied again, and the same loss of r. p. m. was experienced. Realizing that the attempt to break the sink rate would be unsuccessful, the pilot executed a full flare, close to the ground, and committed the aircraft to a crash landing. Attitude of the aircraft at initial impact was approximately 20 degrees, nose up, with a 30-degree right roll.

Initial contact with the ground occurred on the tail skid, followed by contact of the tail boom. The indicated air speed at this time was 60 knots. The boom failed immediately forward of the tail rotor pylon and was bent upward and forward. As the main fuselage continued to descend, the right skid struck the ground. At this point, one of the main rotor blades severed the tail rotor drive shaft above the horizontal stabilizer. The helicopter then rebounded into the air and struck the ground a second time with approximately a 30-degree left roll. The main rotor blade again struck the tail boom, severing it approximately 6 inches forward of the horizontal stabilizer. Following this impact, the helicopter again became airborne, turned approximately 90 degrees to the left about its vertical axis, continuing in its original line of flight, and struck the ground a third time. From this point, the remaining fuselage rolled one and one-half times about its longitudinal axis in contact with the ground, coming to rest inverted. During the roll, various components were torn free and dispersed throughout the area. Figures 1 and 2 show the manner in which the helicopter came to rest; Figure 3 shows the sequence of action during the crash.

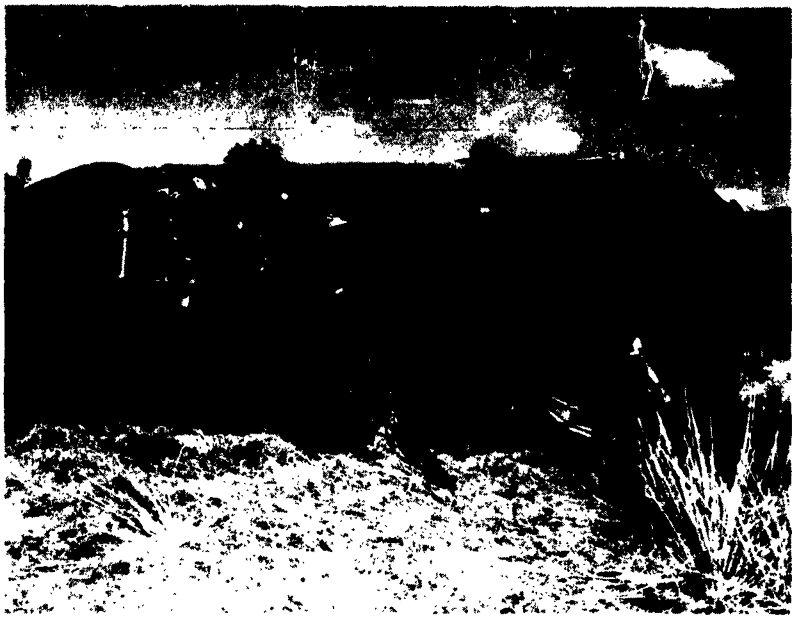

Figure 1. Overall View of the Helicopter's Right Side.

Figure 2. Overall View of the Helicopter's Left Side.

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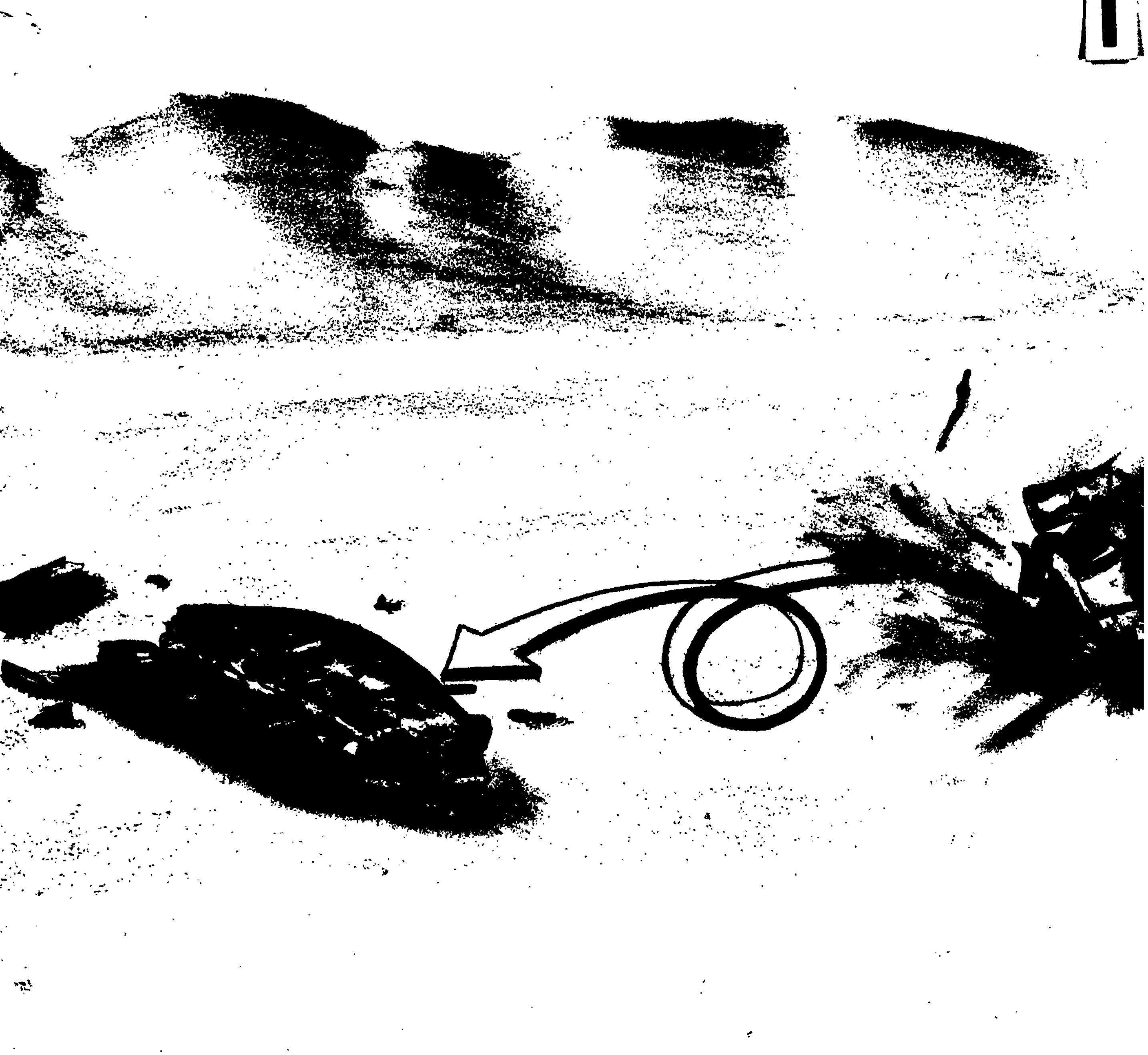

Figure 3. Kinematics of Crash Sequence.
(1) shows impact at right skid. (2) shows impact at left skid.

EVACUATION

The pilot and copilot required assistance in their evacuation because of incapacitating injuries and being "pinned" in the wreckage. The pilot was removed from the wreckage while still strapped in his seat. To expedite the administering of first aid, both the pilot and copilot's shoulder harnesses and seat belts were cut by personnel assisting in the evacuation.

The two passengers seated on the inboard troop seats released their seat belts and evacuated the wreckage without assistance, immediately after the helicopter came to rest.

The left outboard passenger was extricated from the wreckage by personnel assisting with the evacuation and by the two passengers mentioned in the previous paragraph. In the confusion following the accident, the right outboard passenger was not immediately discovered, as he was partially covered by wreckage of the aircraft and field equipment carried aboard by all the passengers. In an attempt to account for all passengers, it was noted that this passenger was missing; a subsequent search of the aircraft revealed his body.

DAMAGE TO THE AIRCRAFT

Accident experience in the HU-1A has revealed a trend of structural failures which was repeated in this accident. A complete discussion of the most significant failures as related to injury has been presented in previous AvCIR reports and will be referenced in this section.

It is important to point out that the manufacturer is aware of these structural deficiencies in the HU-1A and has strengthened and modified several vital components in the HU-1B and HU-1D.

EXTERIOR

The helicopter's roof is supported by the right and left door posts and the aft bulkhead. Both door posts failed at the roof and floor level. The aft bulkhead failed at the roof and service deck level.* Failure of these components permitted the roof to collapse downward into the occupiable area. Overall volume reduction to the cabin was approximately 40 percent, with the cockpit sustaining the greater reduction. Complete volume reduction of the cockpit was prevented by the co-pilot's seat, which became "wedged" between the roof and floor. These failures are shown in Figure 5.

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*Carroll, J., et al, U. S. Army HU-1A Bell Iroquois Helicopter Accident, East St. Louis, Illinois, CRD 2859, AvCIR-10-PR-110, Aviation Crash Injury Research, Phoenix, Arizona, January 1960.

Roegner, H. F., Carroll, J., U. S. Army HU-1A Bell Iroquois Helicopter Accident, Fort Carson, Colorado, TREC Technical Report 60-72, AvCIR 12-PR-122, prepared by Aviation Crash Injury Research, Phoenix, Arizona, for U. S. Army Transportation Research Command, Fort Eustis, Virginia, December 1960.

Roegner, H. F., et al, U. S. Army HU-1A Bell Iroquois Helicopter Accident, Fort Bragg, North Carolina, TREC Technical Report 60-71, AvCIR 13-PR-123, prepared by Aviation Crash Injury Research, Phoenix, Arizona, for U. S. Army Transportation Research Command, Fort Eustis, Virginia, December 1960.

Roegner, H. F., Summary Evaluation of U. S. Army HU-1A Bell Helicopter, TREC Technical Report 60-73, AvCIR 15-PR-126, prepared by Aviation Crash Injury Research, Phoenix, Arizona, for U. S. Army Transportation Research Command, Fort Eustis, Virginia, December 1960.

In the HU-1B, the manufacturer modified each door post by increasing the gauge thickness of the sheet-metal structure. This modification increased the load-carrying capability of each post from 1, 750 pounds to 2, 690 pounds. The aft bulkhead, beginning with ship number 47 (in the HU-1B series), has had its vertical load-carrying capability increased from 14, 900 pounds to 35, 000 pounds by changing the sheet-metal construction to honeycomb-type construction.

In the HU-1D, the door posts have been designed to carry structural loading and extend up to the roof beams to form, in effect, a complete roll-over structure.*

These modifications in the HU-1B and HU-1D have given these two helicopters an improved level of crashworthiness over the HU-1A. A study was conducted by the manufacturer to determine a method of reducing the possibility of roof collapse during moderate crash conditions in the HU-1A. Two approaches for retrofit resulted from this study. The first approach involved the modification of each door post. This modification is mentioned in a previous paragraph as being performed in the HU-1B. The second approach provided for the addition of roll-over structure to each crew seat. This modification would add approximately 3. 5 pounds per helicopter and would be capable of withstanding a vertical load of 3, 500 pounds per seat. Neither of these two retrofit proposals has been incorporated in the HU-1A.

INTERIOR

Failure of both crew seats was the major damage to interior components. The design and method of installation of each crew seat are identical. Each seat is adjustable in the fore-and-aft direction by means of guide channels and floor-anchored tracks. The height of seat bucket and seat frame can be adjusted by means of a sliding mechanism around the two rear seat legs. The rear legs are attached to the guide channels with magnesium alloy cast fittings. The front legs are bolted to a cross tube that connects the front end of the two channels.

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* Carroll, J., U. S. Army YHU-1D Bell Iroquois Helicopter Mockup Evaluation, Fort Worth, Texas, TREC Technical Report 60-74, AvCIR 16-PV-127, prepared by Aviation Crash Injury Research, Phoenix, Arizona, for U. S. Army Transportation Research Command, Fort Eustis, Virginia, February 1961.

Failure of the pilot's seat installation occurred in the left rear attachment fitting, in the front left bolt that anchors the seat leg to the attachment fitting, and in the forward portion of the right guide channel; and a section of the aft right track pulled free from its anchoring bolts. The various failures are shown in Figures 6 and 7.

Failure of the copilot's seat occurred in both rear attachment fittings and in both front bolts that anchor the seat legs to the attachment fittings. Damage was sustained by the top of the seat back from being "wedged" between the cockpit floor and roof. Deformation to the left side of the seat pan consisted of "popped-out" rivets and torn metal. The various failures are shown in Figures 8 and 9.

Because of the active kinematics of the helicopter during the crash sequence, it is difficult to determine the exact sequence of failure in the crew-seat anchorages. It is of significance, however, that the location of the failure has appeared in previous HU-1A accidents. Past history indicates that initial failure occurs at the rear-leg attachment fittings. As a result, the front-leg anchorage acts as a pivoting point for the seat/occupant combination until the retaining bolts fail. Consequently, the crew seats and occupants have been thrown completely out of the helicopter. *

The same crew-seat anchorage arrangement exists in the HU-1B and HU-1D; however, in the HU-1D, the seat belts and shoulder harness are anchored to basic aircraft structure rather than to the seats. This change in installation will result in a significant reduction of inertia loads being placed on the rear attachment fittings by the seat/occupant combination during crash load conditions. Thus, the occupant safety factor is further improved in the HU-1D.

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* Roegner, H. F., et al, U. S. Army HU-1A Bell Iroquois Helicopter Accident, Fort Bragg, North Carolina, TREC Technical Report 60-71, AvCIR 13-PR-123, prepared by Aviation Crash Injury Research, Phoenix, Arizona, for U. S. Army Transportation Research Command, Fort Eustis, Virginia, December 1960.

Roegner, H. F., Summary Evaluation of U. S. Army HU-1A Bell Helicopter, TREC Technical Report 60-73, AvCIR 15-PR-126, prepared by Aviation Crash Injury Research, Phoenix, Arizona, for U. S. Army Transportation Research Command, Fort Eustis, Virginia, December 1960.

Figure 6. Failure of Pilot's Seat Installation.
(The circles indicate the points of failure.)

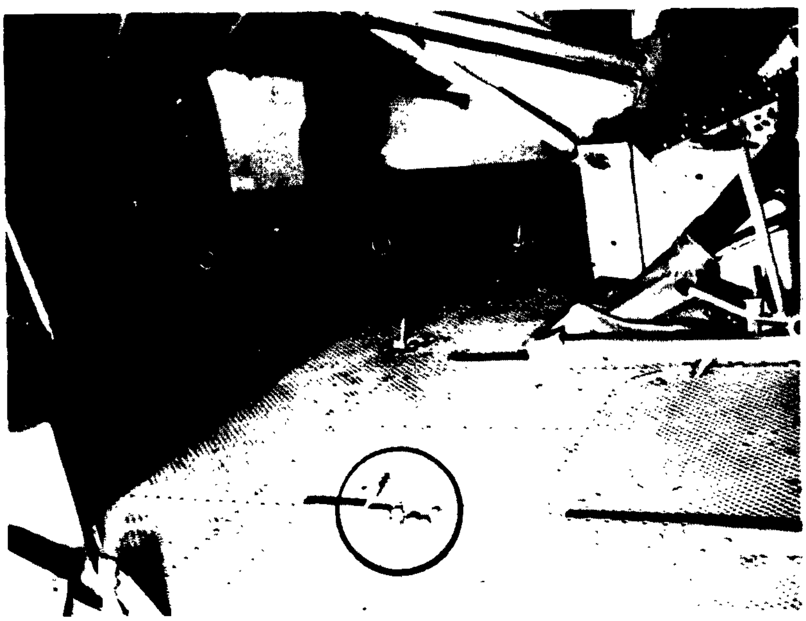

Figure 7. Failure of Pilot's Seat Anchorages.
(The circle indicates the floor track failure.)

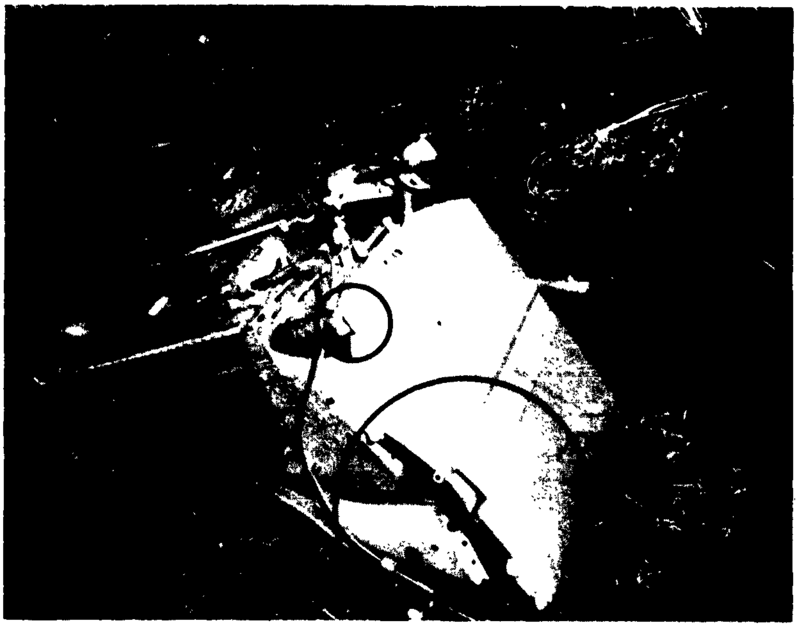

Figure 8. Failure of Copilot's Seat Installation.
(The circles indicate the points of failure.)

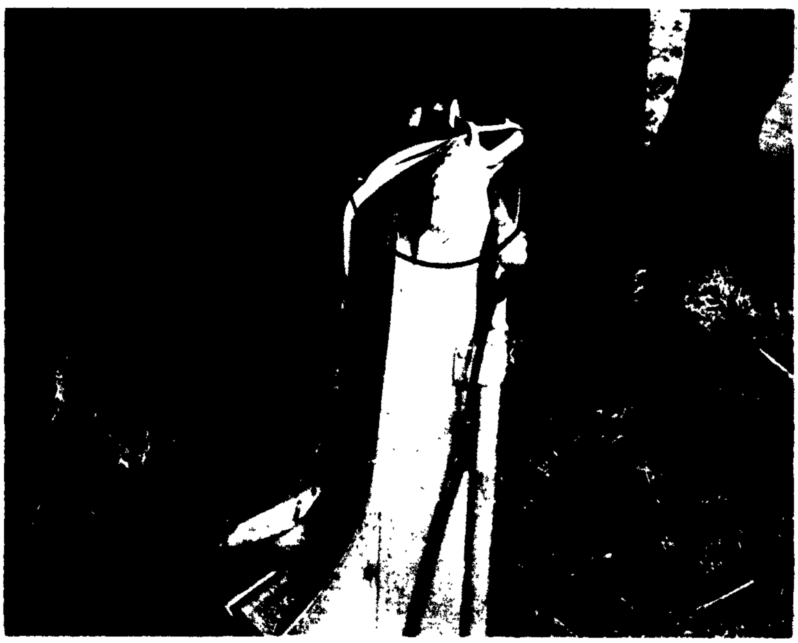

Figure 9. Damage to Top of Copilot's Seat Back (Circle).

A method of improving occupant safety in the HU-1A and HU-1B, relative to crew-seat anchorage, has been devised by the AvCIR Engineering Section. The complete analysis is presented in a crash injury bulletin.* In essence, the improvement consists of a modification to the aft attachment fittings. This modification can be conducted in the field without the need of manufacturing additional parts. Furthermore, it is estimated that this modification will effectively double the strength (20+G) of these fittings. Preliminary analysis of the other components of the "tiedown chain" indicates that the total seat strength can be increased to over 20G with relatively minor modifications of these components.

The pilot's safety belt and shoulder harness were cut in order to remove him from the seat. Although his inertia reel was found to be unlocked and the handle was in the unlocked position, it is believed that the reel functioned properly and may have been unlocked during the evacuation. The copilot's safety belt and harness were also cut in order to remove him from the seat. The inertia reel was found to be locked and the control handle was in the unlocked position, which clearly indicated proper operation during the crash acceleration.

The standard military troop seats in the HU-1A are designed to MIL-S-5804B. The seat frame consists of upper, rear, and front support tubes to which are attached the nylon seat back and seat pan. The seat legs are attached to the front support tube. Curved spreaders maintain the distance between the front and rear support tubes. Figure 10 illustrates the design. The upper support tube was the only portion of the troop-seat structure which failed in this accident. The failure probably occurred when the upper portion of the aft bulkhead, to which the upper support tube is attached, folded rearward during the roll portion of the accident sequence. The extreme left seat leg was "popped" loose from its floor anchorage. The floor anchorage, together with a small section of the floor, was pulled down by structure beneath the floor. Apparently this occurred when the fuselage struck the ground during the initial portion of the crash sequence. Figure 11 shows the floor and anchorage. All the seat legs and seat pan hardware remained intact. The passengers' seat belts showed no damage except for being cut by rescue personnel.

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* Avery, J. P., Ph. D., <u>Strength Analysis of Carriage Attachment Fitting on Crew Seats, HU-1A Aircraft, and Recommendations for Improvement,</u> TCREC Technical Report 62-84, AvCIR 62-11, U. S. Army Transportation Research Command, Fort Eustis, Virginia, October 1962.

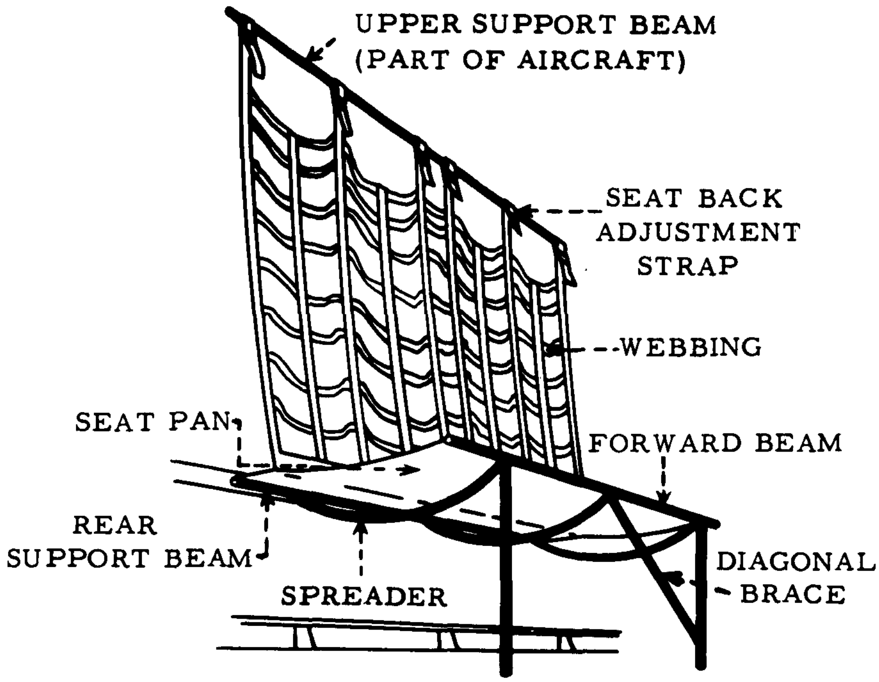


Figure 10. Typical Troop Seat Design.

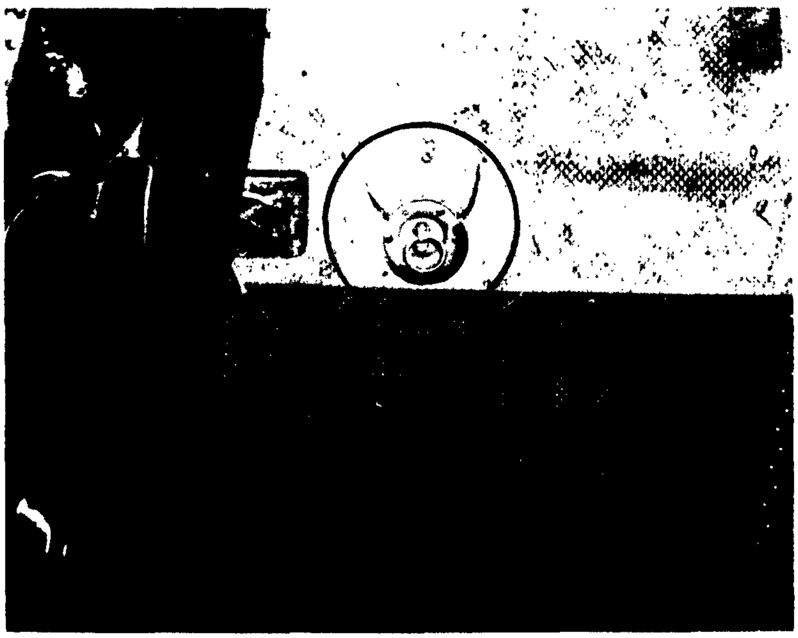


Figure 11. Damage to Floor Beneath Left Troop-Seat Leg.

CRASH INJURY ANALYSIS

GENERAL

The analysis of the crash injuries sustained in this accident was based on the five factors which are commonly considered to be the injury mechanisms in aircraft accidents. A description of these factors is contained in Appendix II.

The crash forces in this accident were relatively moderate, and no injuries were due purely to decelerative forces. All injuries were the result of failure and collapse of cockpit and cabin-roof structure, contact with various environmental items, and erratic behavior of the restraint systems. This is readily apparent from Figure 12. The dynamics producing the injuries are, for the most part, related to insufficient crashworthiness of the aircraft's basic structure and to inadequate personnel restraint. This accounts for the difference in injury patterns seen in the crew-seat occupants as compared with the passengers located in the aft portion of the cargo compartment.

Figure 13 discloses the importance of lack of crashworthiness as an injury-causing agent in this accident. Three of the six passengers suffered either serious or severe injuries by this mechanism, and one of these later died as a result of his injury. Environment was partially responsible for one minor injury and contributed to one severe injury. Restraint was responsible for one minor injury and contributed to one severe and one minor injury. Postcrash factors and decelerative forces were not primarily responsible for any of the injuries.

INJURIES DUE TO LACK OF CRASHWORTHINESS

The occupants of the pilot and copilot seats both suffered injuries as a result of the collapsing roof when the aircraft rolled over. They both were secured in their seats by lap belts and shoulder harness. When the roof collapsed, they were compressed in their seats, resulting in the compression fractures of the pilot's T7, 8, and the copilot's T8, 9 thoracic vertebrae, as well as in the pilot's concussion, and in the contusions and lacerations of both of their heads and upper torsos. The pilot's head was protected by an APH-5 helmet, which prevented more severe injury (discussed separately under protective gear).

The crushing injuries were not more severe only because the backs of the crew seats supported the roof and thus prevented the roof from

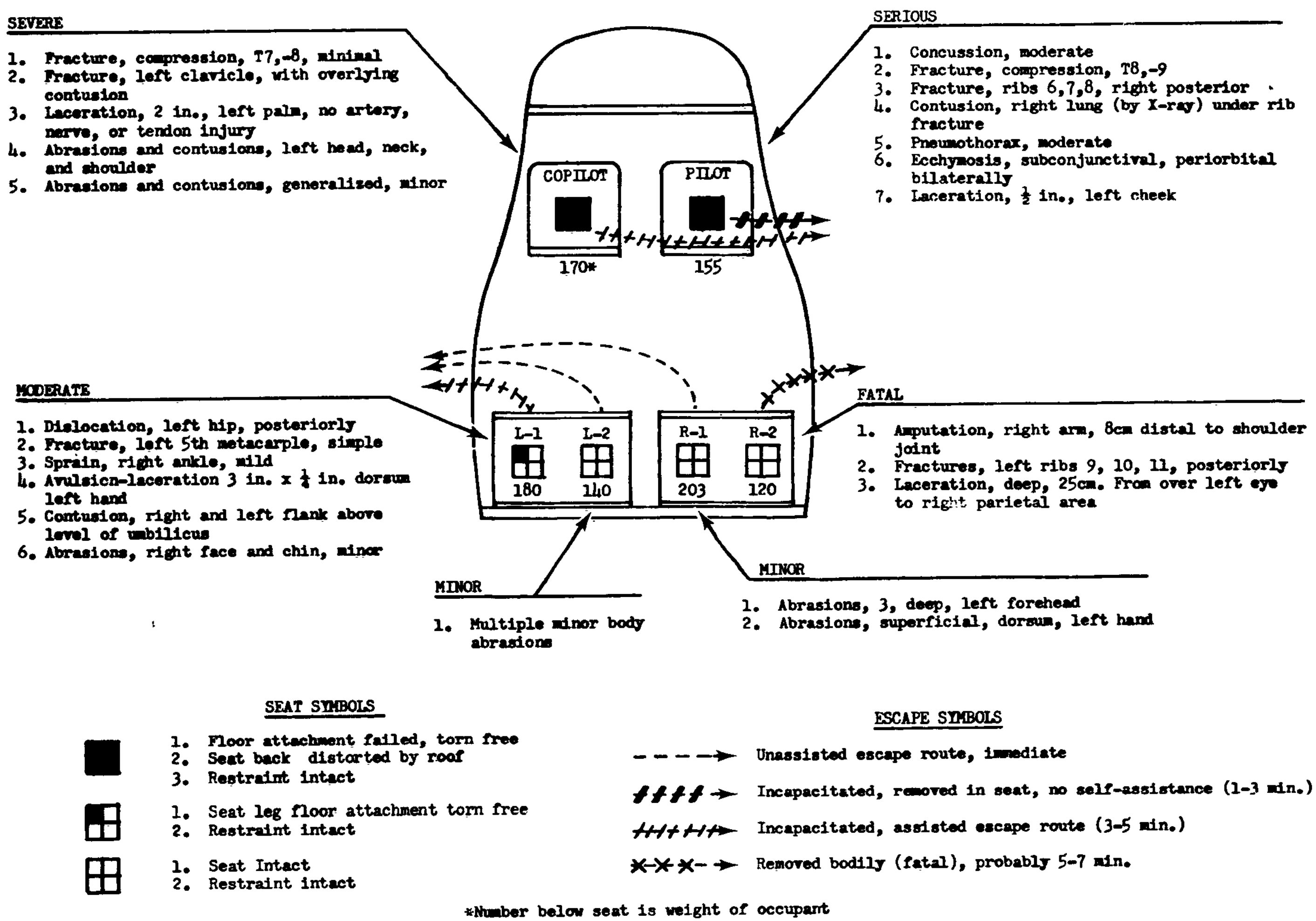


Figure 12. Escape Transpositions, Seat Damage, and Injury.

Occupant	Degree of Injury	CAUSATIVE FACTORS: Crash-worthiness	Environ-ment	Restraint	Postcrash Factors	Decel-erative Forces	Other Factors
PILOT	Serious Concussion, Fractured Thoracic Vertebrae, Facial Laceration	Roof collapse in roll-over	No	No	No	No	Helmet transmitted force beyond tolerable limits
COPILOT	Severe Fractured Thoracic Vertebrae, Left Clavicle	Roof collapse in roll-over	No	No	No	No	
L-1	Minor Contused Flanks Moderate Dislocated L/Hip	No	No	Seat Belt anchored too high-submarining	No	No	Anchoring of internally rotated heel with knee locked in hyperextension
L-2		No	No	No	No	No	No
R-1	Minor Contusion of Forehead	No		Lack of shoulder harness allowed flexing against back of crew seat	No	No	No
R-2	Severe Amputated R/Arm at Shoulder, Fracture of Ribs 9, 10, & 11, Left Fatal Exsanguination	No		Flailing of extremities, Lap belt anchored too high-submarining	No	No	Absence of prompt attention to amputation

Figure 13. Degree of Injury as Related to Crash Injury Causative Factors.

collapsing more completely. The cargo compartment occupants were protected from crushing injuries by the firewall, which prevented the rear portion of the roof from collapsing on them.

The fact that the doors of the HU-1A came off probably was a factor in the amputation of passenger R-2's right arm. The removal of the doors is not considered an overall detrimental feature, as in the majority of accident cases this feature expedites passenger evacuation. His arm was cleaved off as the aircraft made its first roll to the right, and it was found intact in the immediate area of the aft portion of the right skid. It is not possible to determine exactly how his arm was amputated, but as the craft rolled to the right and the door popped off, his arm was thrown out of the right doorway, either because he was bracing himself against this door, or due to inertial forces. His arm was then cleaved off cleanly 8cm distal to the shoulder joint by being forced against the outboard edge of the firewall, as is evidenced by the presence of residual tissue in this area. Whether it was cleaved off by the door or the right skid is not apparent by examination of these items; the amputated arm showed no pertinent evidence to the examining pathologist. The sleeve and arm were entirely intact, showing no evidence of being abraded off by the ground. Death followed by exsanguination.

INJURIES RESULTING FROM INADEQUATE RESTRAINT

A second factor which may have contributed to passenger R-2's arm being amputated was the restraint system. He was restrained by a lap belt only. Thus, as the aircraft rolled to the right, he had no lateral upper torso restraint, some of which could have been provided by a tight shoulder harness. Consequently, his upper torso was forced to the right and his arm was thrust out of the door opening.

A recent modification which has been carried out in this aircraft specified that the lap belt for the troop-seat passengers is to be anchored to the aft cross tube of the troop seat rather than to the normal anchorages (due to the fragility of these cast attachments). As a result, this high restraint allows the lap belt to ride high above the iliac crests. This improper restraint angle allowed "submarining" of two passengers (R-2, L-1). R-2 received fractures of ribs 9, 10, and 11 posteriorly on the left, inflicted as his lap belt slipped up around his chest; in addition, he received a head laceration. L-1 received contusions of his flanks and abdomen above the level of his umbilicus (Figure 14).

Figure 14. Flank Contusion Above Level of Umbilicus Due to Seat Belt. (Passenger L-1.)

INJURIES DUE TO CONTACT WITH ENVIRONMENT

The injurious environment in this accident developed as a result of the failures listed above, and thus cannot be described with any degree of finality. The contusion to R-1's forehead could have occurred as a result of his flexing forward and contacting the back of the pilot's seat or other environmental structure. The possibility also exists that the lack of lateral restraint, after the door popped off, left him with no protection from the outside when the aircraft rolled over.

INJURIES DUE TO POSTCRASH FACTORS

Neither postcrash fire nor water contributed to the injuries resultant from this accident.

ROLE OF SPECIAL PROTECTIVE GEAR

The pilot was the only occupant wearing an Army APH-5 helmet. During the roll-over part of the crash sequence, his head was thrown

to the right. As the roof collapsed, his head protruded out of the cockpit window, allowing the helmet to abrade against the ground on the right posterior aspect. It is not known whether the helmet was retained during the entire crash, but the retention system remained intact. The right earphone came loose because the retraction cord was torn when the helmet abraded the ground.

Possibly the most significant damage to the helmet is shown in Figure 15. The shell immediately underlying the left visor keeper is fractured in two places. The reason that these cracks are significant is that the force of the blows to the helmet were great enough to cause this cracking even before any deformation of the energy-absorbing liner occurred. Thus, the shell began to break down and would have failed prematurely, which would have allowed local transmission of forces to the pilot's head under the keeper.

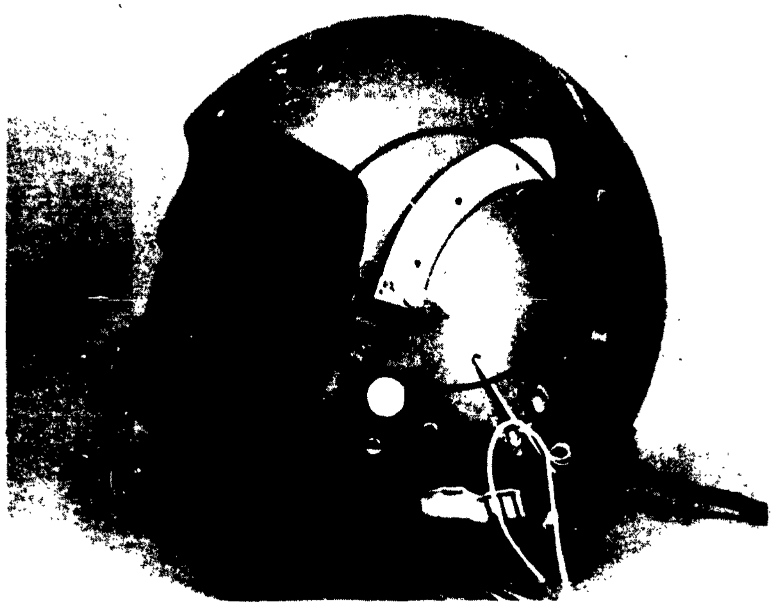


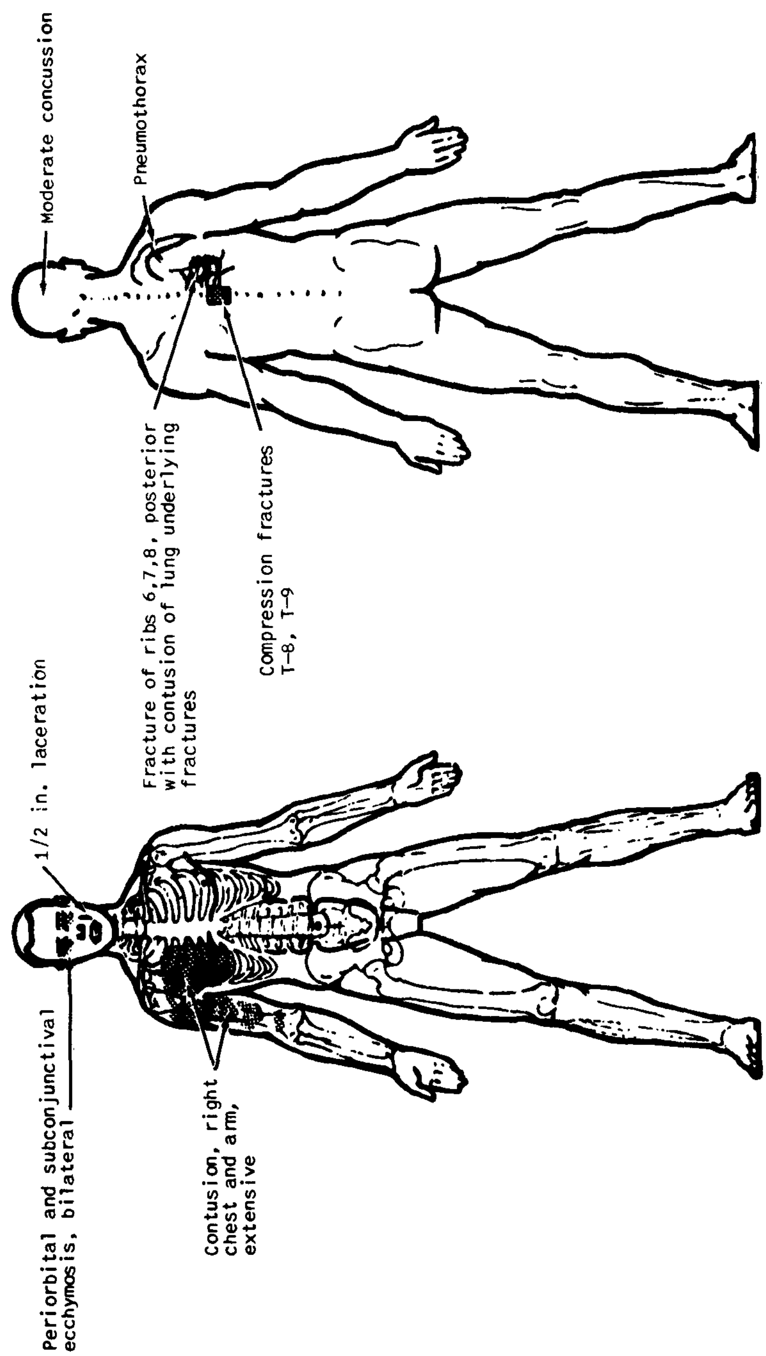
Figure 15. View of Damage Sustained by APH-5 Helmet

Because of a locally fabricated modification to the APH-5, which allowed the wearing of an instrument training hood, the screws on the right visor keeper popped out when the visor housing was struck. This, in itself, was not problematic; however, the locally fabricated hood retention device is a very prominent snagging point.

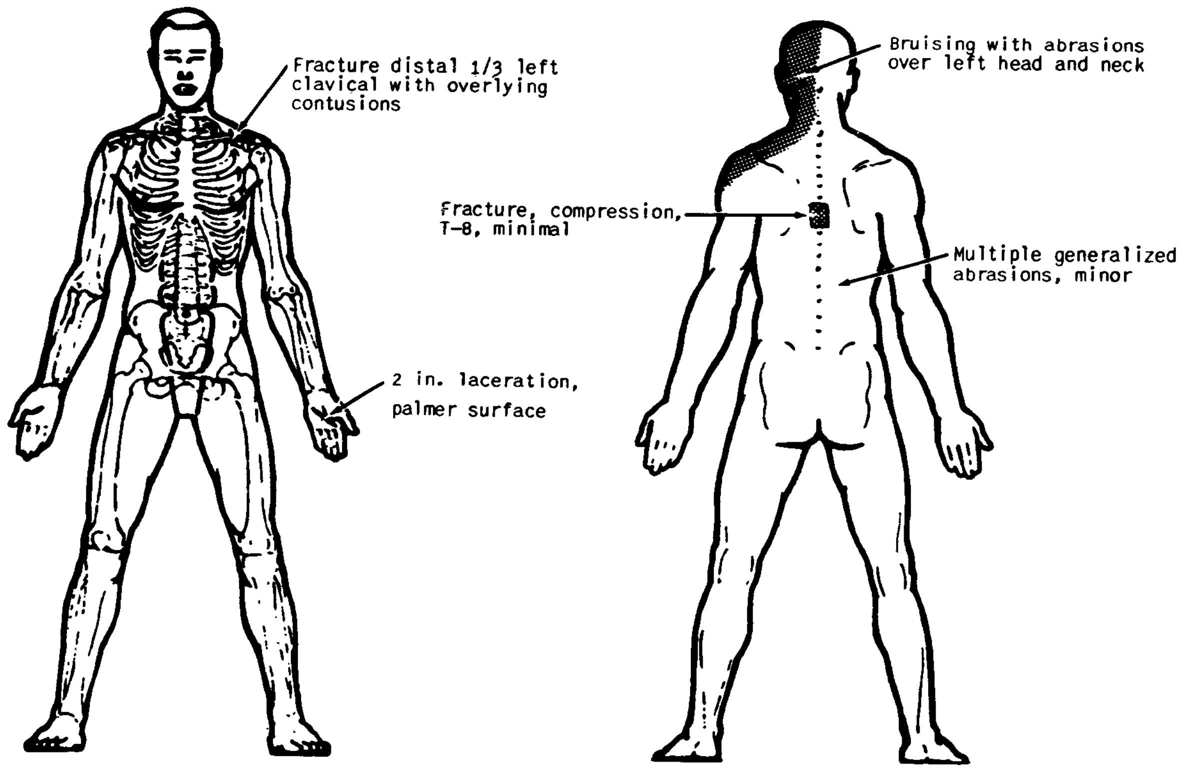
SPECIAL INJURY CONSIDERATIONS

Passenger L-1 suffered an injury to his left hip which cannot be attributed to any of the usual categories of crash injury. When this passenger realized that a crash was imminent, he prepared himself by bracing himself in his seat. One of the bracing gestures he used was to plant his left heel firmly against the air vents at the bottom of the forward cargo compartment side wall. This placed his leg in an internally rotated position. He then flexed forward with his chest on his thighs. This position allowed for easy posterior dislocation of the femoral head out of the acetabulum without other injury to the pelvis or femur, when he was accelerated forward and floorward against the anchored heel.

APPENDIX I. MEDICAL REPORTS



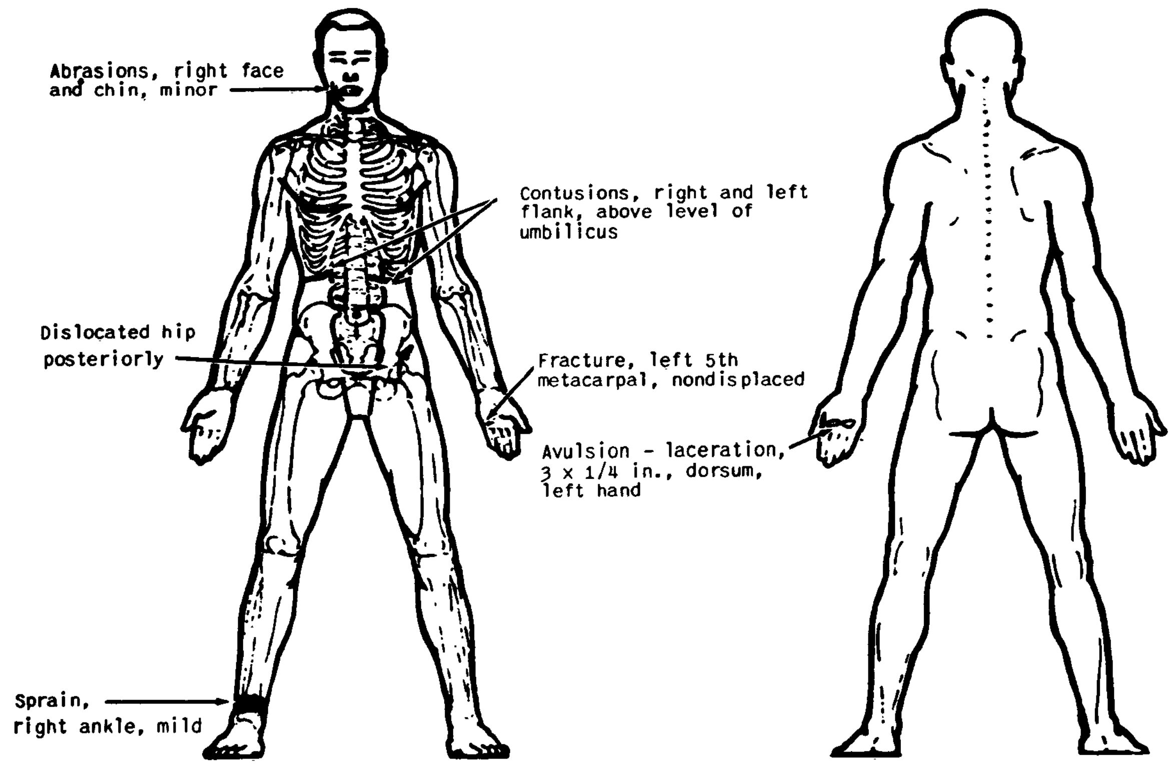
PILOT - RIGHT SEAT
HU-1A ACCIDENT, FORT CARSON, COLORADO
7 MAY 1962



COPILOT - LEFT SEAT

HU-IA ACCIDENT, FORT CARSON, COLORADO

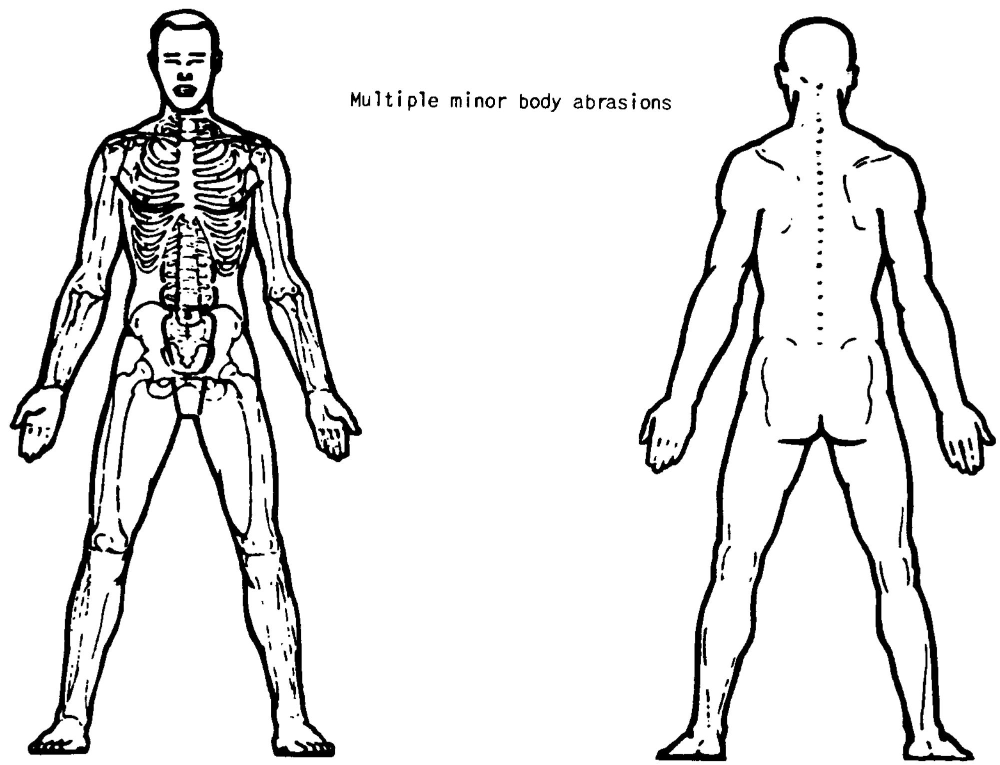
7 MAY 1962



PASSENGER - TROOP SEAT L-1

HU-1A ACCIDENT, FORT CARSON, COLORADO

7 MAY 1962



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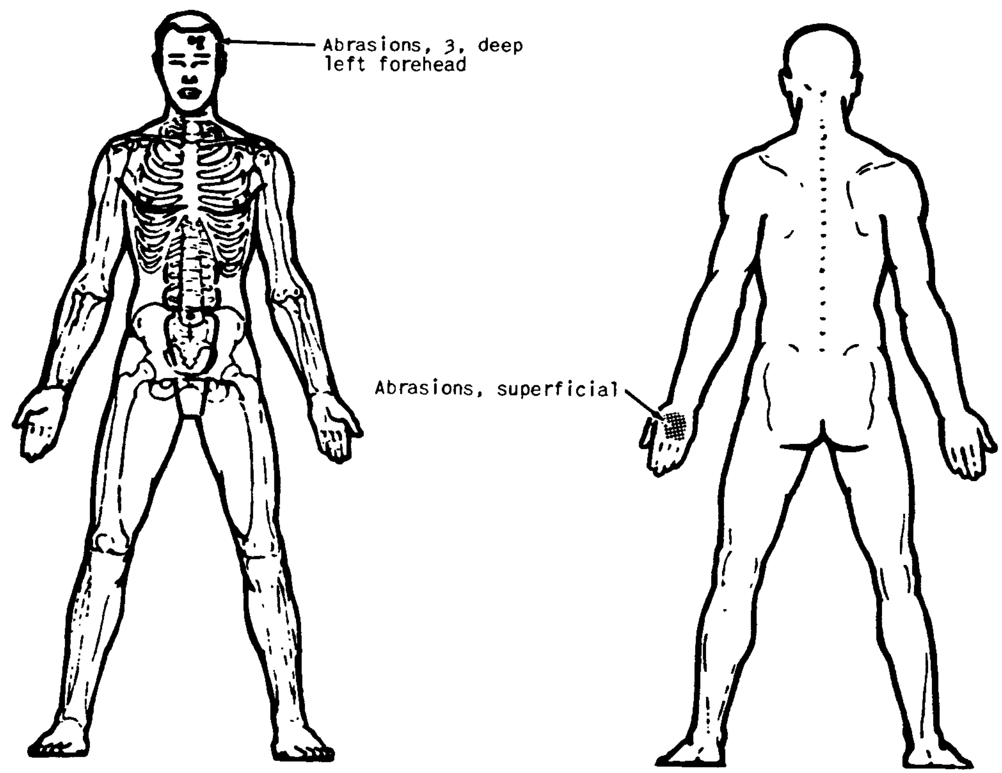
7 MAY 1962



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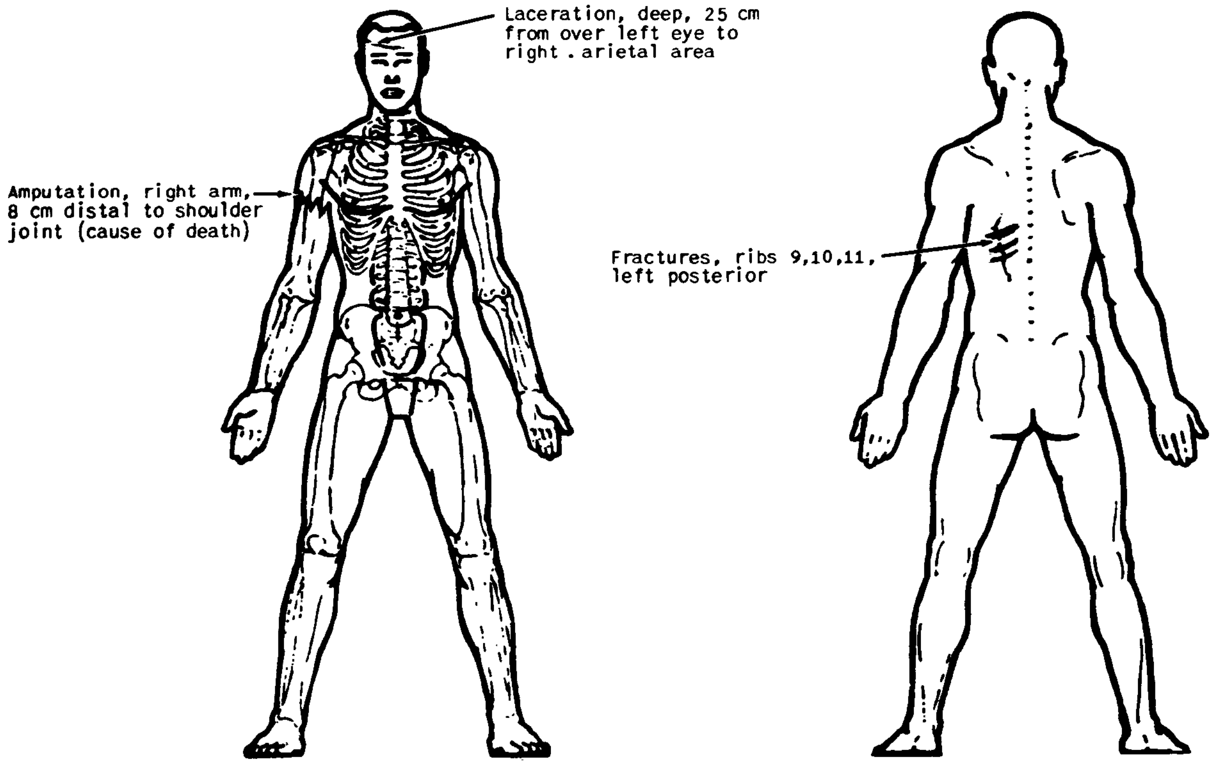
HU-1A ACCIDENT, FORT CARSON, COLORADO
7 MAY 1962



PASSENGER - TROOP SEAT R-2

HU-1A ACCIDENT, FORT CARSON, COLORADO

7 MAY 1962

APPENDIX II. SUMMARY OF CRASH SAFETY CRITERIA

SUMMARY OF CRASH SAFETY CRITERIA

In its efforts to determine the crash survival aspects of aircraft accidents AvCIR, a Division of the Flight Safety Foundation, is guided by certain criteria which it considers fundamental for the crash protection of aircraft occupants. The same criteria are also used to evaluate the crash safety features of mock-ups and prototypes.

CRASHWORTHINESS

Crashworthiness may be defined as the ability of basic aircraft structure to provide protection to occupants during survivable impact conditions. Impact conditions are considered survivable in that part of the cockpit/cabin area where the crash forces are within the limits of human tolerance (with minimal or no injury)* and where surrounding structure remains reasonably intact.

Lack of crashworthiness, generally, indicates that the basic aircraft structure, seen as a protective container, is subject to extensive inward collapse thereby affecting the "inhabitability" of this area. Typical in this respect are (1) the rearward movement of the engine in single engine aircraft; (2) the downward displacement of transmissions and other heavy components in helicopters; (3) the upward collapse of lower structures into the cockpit/cabin area. This deformation or collapse of the occupiable area may result in crushing type injuries or trapping of the occupants.

When evaluating the crashworthiness of basic aircraft structure, stress is placed upon the expected behavior of this structure during a survivable type impact. Attention is also given to anticipated dynamic response under the most probable conditions of impact angle and aircraft attitude, based upon accumulated past experience. This facilitates an appraisal of the possibility of displacement of certain heavy components into the occupiable area as a result of inertia forces.

TIE-DOWN CHAIN

Although a crashworthy structure provides primary protection during a crash deceleration, injuries may still occur when occupants are allowed to come into forceful contact with their environment or to be struck by loose objects thrown through the occupiable area. The restraint system used to prevent occupants, cargo and components from being thrown loose within the aircraft is commonly referred to as the tie-down chain. The occupant's tie-down chain consists of: seat belt, seat belt anchorage, shoulder harness and anchorage, seat structure, seat anchorages and floor. Failure of any link in this chain results in a higher degree of exposure to injury.

Accident statistics indicate that the site of most serious and frequent injury in general aviation accidents is the head. In most cases, this is due to lack of restraint, allowing the head to gain momentum during impact and to strike objects in its path with a force exceeding that of the overall crash deceleration. This is especially true in the case of cockpit occupants who face the instrument panel, control wheel and many other injurious environmental structures. Considering these factors, it is practically impossible to avoid contact injuries during crash deceleration when such occupants are not restrained by a properly installed and properly used shoulder harness of adequate strength in combination with a seat belt.

Although seat structure and anchorages meet static strength tie-down requirements, failures frequently occur as a result of dynamic loads imposed by the occupants on seat belts and shoulder harnesses when these are anchored to the seats instead of primary structure. This type of crash force amplification should be taken into consideration when evaluating the dynamic strength of the occupant tie-down chain. Inadequately or improperly secured aircraft equipment and components in the occupiable area also have an injury potential during crash decelerations. Therefore, the tie-down and stowage of such items as luggage, cargo, radio equipment, fire extinguishers and tool boxes requires careful consideration.

OCCUPANTS' ENVIRONMENT

Accident experience has shown that under many impact conditions occupants who are reasonably restrained within a crashworthy structure may still receive injuries through forceful contact with injurious environmental structures, components, etc. (This is particularly true when shoulder harness is not used.) The freedom of movement of the occupant's body during a crash deceleration is governed by the type of restraint system installed and the manner in which it is used. Generally, it can be stated, however, that injuries resulting from the flailing action of the occupant's body show a peripheral trend; that is, the areas farthest away from the seat belt receive most of the injuries (head and lower extremities).

To preclude the probability of injury through striking injurious environment, the limitations of the restraint system should be used as a guide for the extent to which the occupant's environment should be made harmless. The injury potential of all objects and structure within striking range, omni-directionally, can be reduced to a minimum by such measures as elimination of sharp surfaces, safety-type control wheels, breakaway features in instrument panels, use of ductile or energy-absorbing material wherever possible.

*Approximately 40G transverse to the spine, 25G parallel to the spine (positive G), 15G parallel to the spine (negative G) with due consideration for peak magnitude, duration, rate of onset, and method of body restraint. J.P. Stapp, Human Exposure to Linear Deceleration, Part 2. The Forward-Facing Position and the Development of a Crash Harness. WADC, Wright-Patterson AFB, Ohio, Dec. 1951. A.F.Technical Report No. 5915, Part 2.

TRANSMISSION OF CRASH FORCE

Another independent injury-producing factor presents itself in the fact that crash forces may be transmitted or even magnified through rigid aircraft structures. This is usually associated with "bottoming out" on structures incapable of absorbing or reducing crash force. Although crash force in most accidents is applied in a direction oblique to the occupant's spine, it is customary to resolve vertical and horizontal components of the crash force resultant and relate these to the human G-force tolerance levels, either parallel or transverse to the spine. A normally seated person, when effectively restrained by a seat belt and shoulder harness, can tolerate (with minimal or no injury) approximately 40 G transverse to the spine, 25 G parallel to the spine in the foot-to-head direction (positive G), 15 G parallel to the spine in the head-to-foot direction (negative G).

Injuries attributed solely to transverse G will seldom be encountered in aircraft accidents, because collapse of structure and/or failure of the restraint system will most likely occur before the limit of transverse G tolerance (40 G) is reached. This is an undesirable situation. Although operational and economic considerations impose limits on the overall fuselage strength, the occupant tie-down chain should be more compatible in strength with tolerance levels of the body.

Accident experience has shown that injuries directly attributed to the transmission or magnification of crash force are usually associated with predominantly vertical impacts. Vertebral injuries are most often associated with vertical crash force application.

The seat, as the occupant's supporting structure, and the underlying floor structure are the media through which vertical forces are usually transmitted to the occupant. The dynamic response of these media during an impact determines the manner in which the forces acting on the aircraft structure can be modified before reaching the occupant. An extremely rigid structure, which normally is not found in aircraft, would transmit the forces without modification. An elastic structure, which has energy-storing properties, may modify the magnitude and other characteristics of decelerative force to the extent that amplification takes place. For example, a foam rubber cushion (which does not offer an appreciable resistance to compression) allows an occupant to "bottom out" against rigid seat and seat pan structures during a vertical impact. A more desirable situation would be that in which the structure between the occupant and the point of impact had high energy-absorbing characteristics. This may be achieved by the use of structure which collapses progressively without failing suddenly. This ideal form of crash energy absorption results in attenuation of the crash forces transmitted to the occupant. It is one of the basic methods for the incorporation of occupant protection in aircraft design.

POST-CRASH FACTORS

Although a distinction could be made between the prevention of injuries sustained in the dynamic phase of the impact and those sustained in the post-crash events, it is felt that the overall crash survival concept does not allow this distinction. Past experience has shown that accidents involving only very minor impact forces can become catastrophies as a result of post-crash factors.

One of the greatest hazards in an otherwise survivable accident is the possibility of a post-crash fire. These fires, normally, are of a sudden nature and may severely restrict the time available for evacuation. According to a NACA study (Technical Note 2996), not more than 50 seconds may be available for escape in all but the most severe fires, although in some cases passengers must move away from areas of burned-through fuselage in as few as 7-1/2 seconds. This time element becomes even more critical when occupants are handicapped by such factors as disabling injuries, stunned condition, unfamiliarity with the seat belt release or the operation of the emergency exits, being trapped, and panic.

Control of post-crash fires, to some extent, is governed by design (location of fuel cells and fuel lines in relation to electrical and mechanical ignition sources; resistance of fuel system components against rupture under conditions of moderate crash forces or distortion). Other preventive measures include location of fire extinguishers at strategic points and automatic emergency or impact-operated fire extinguishing systems.

In the event of a post-crash fire or a ditching, the ability of all occupants to timely evacuate the aircraft probably becomes the most important survival factor. The evacuation time is a function of the number, location and adequacy of the normal and emergency exits.* The location and emergency operation of normal and emergency exits should be obvious even to the non-experienced passenger. Hand or impact-operated emergency lights can be of vital importance during evacuation in conditions of darkness or subdued light.

*HIAD (the military Handbook of Instructions for Aircraft Designers) requires "a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching, in 30 seconds by trained personnel representing the crew and all passengers."

APPENDIX III. SCALE OF INJURY* USED BY AvCIR
(Revised 4/60)

Degree of Injury	Classification and Description of Injury
None or Trivial	No Injury - Abrasions or scratches of a superficial nature.
Minor	"Minor" contusions, lacerations, abrasions in any area(s) of the body. Sprains, fractures, dislocations of fingers, toes, or nose. Dazed or slightly stunned. Mild concussion as evidenced by mild headache, with no loss of consciousness.
Moderate	"Moderate" contusions, lacerations, abrasions in any area(s) of the body. Sprains of the shoulders or principal articulations of the extremities. Uncomplicated, simple, or green-stick fractures of extremities, mandible and rib cage (excluding spine). Concussion as evidenced by loss of consciousness not exceeding 5 minutes, without evidence of other intracranial injury.
Severe (survival normally assured with prompt medical care and without complications)	Extensive lacerations without dangerous hemorrhage. Compound or comminuted fractures, or simple fractures with displacements. Dislocations of the arms, legs, shoulders or pelvisacral processes. Fractures of the facial bones excluding mandible. Severe sprains of the cervical spine. Fractures of transverse and/or spinous processes of the spine, without evidence of spinal cord damage. Fractures of vertebral bodies of the dorsal and/or lumbar spine, without evidence of spinal cord damage, or compression fractures of L-3-4-5 without evidence of damage to nervous system. Skull fracture without evidence of concussion or other intracranial injury. Concussion as evidenced by loss of consciousness of over 5 and up to 30 minutes, without evidence of other intracranial injury.
Serious (but survival probable)	Lacerations with dangerous hemorrhage. Fractures or dislocations of vertebral bodies of the cervical spine, without evidence of spinal cord damage. Compression fractures of vertebral bodies of dorsal spine and/or of L-1 and L-2 without evidence of spinal cord damage. Compression fractures of L-3-4-5 with

* Based on observations during first 48 hours after injury and previously normal life expectancy.

Degree of Injury	Classification and Description of Injury
Serious (cont'd)	evidence of damage to nervous system. Crushing or multiple fractures of the extremities and/or of the chest. Indication of moderate intrathoracic or intra-abdominal injury. Skull fracture with concussion as evidenced by loss of consciousness up to 30 minutes. Concussion as evidenced by loss of consciousness of over 30 minutes to 2 hours, without evidence of other intracranial injury.
Critical (survival uncertain or doubtful. Includes fatal termination beyond 24 hrs.)	Evidence of dangerous intrathoracic or intra-abdominal injury. Fractures or dislocations of vertebral bodies of cervical spine with evidence of cord damage. Compression fractures of vertebral bodies of dorsal spine, and/or L-1, L-2, with evidence of spinal cord damage. Skull fracture with concussion as evidenced by loss of consciousness beyond 30 minutes. Concussion as evidenced by loss of consciousness beyond 2 hours. Evidence of critical intracranial injury.
Fatal within 24 hrs. of accident	Fatal lesions in single region of the body, with or without other injuries classed as Severe.
Fatal within 24 hrs. of accident	Fatal lesions in single region of the body, with other injuries classed as Serious or Critical.
Fatal	Fatal lesions in two regions of the body, with or without other injuries elsewhere.
Fatal	Fatal lesions in three or more regions of the body - up to and including demolition of the body.

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MOCOM	3
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USSTRICOM	1

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Report is made of crash injury investigation involving a U. S. Army (Cont'd.)

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